DEPARTMENT OF SUMMARIES
DEVOTED TO DIGESTS OF PROGRESS IN BIOLOGY

RECENT ADVANCES IN PARASITOLOGY[1]

By Ernest Carroll Faust

Parasitology has made extraordinary progress during the last decade. In writing on this topic ten years ago Ward (1910) states increasing interest in problems of medical zoology had made the mass of material at that time so vast that a review of it was difficult. Since then stupendous progress has been made.

These advances have been due in part to the more general recognition of the importance of this science and the relation of its development to human welfare and in part to the stimulus of the World War. While individual investigators have contributed a great wealth of valuable data to the science, the most outstanding discoveries have come as the result of the work of commissions and bureaus, undertaking fundamental problems of parasitology on a comprehensive scale. Such accomplished facts as the eradication of yellow fever and the minimization of malaria in the Panama Canal Zone, the Hookworm and Tuberculosis campaigns of the International Health Board, and results of the Bilharzia Mission in Egypt are outstanding monuments of progress during this decade.

In attacking the problems in hand the life history of the parasite has been frequently worked out. As in the solution of previous protozoan and helminth diseases, a knowledge of the life history has not only been valuable but in most cases the essential factor in the eradication of the evil. Such a knowledge has shown the most practicable way of breaking the vicious cycle.

As a result of the World War world problems have developed in parasitology from what were formerly matters of Oriental or tropical concern. Troops coming from countries subject to tropical diseases, returning home, have brought infections with them. Such is quite likely the case in such protozoan diseases as amebiasis which require no intermediate host for part of their life cycle. But, in addition, the added impetus which has resulted from the study of such infections as World War problems, has made it evident that the pre-war infection in England and America, for example, was much higher than had previously been believed.

The period has been marked by the development of new laboratories and intensive study of parasitic problems in new fields. In part this

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work has been done by investigators, who, native to the region, have gained distinction in such problems. In part it has been accomplished by commissions which have been sent into the country to make these researches. In part it has been brought about by the efforts of those, who, distant from the field, have diligently sought out a solution to the problems, brought to them by explorers.

The progress in parasitology has been stimulated and cooperation of investigators secured by the appearance of several new Journals devoted entirely or for a major part to parasitology. First must be mentioned the Tropical Disease Bulletin, London, 1913, a review of all the important literature on the subject of tropical parasitology and medicine. The establishment of the Journal of Parasitology (1914) in America affords opportunity for publications of investigations of a type midway between Parasitology of Cambridge and the Annals of the Liverpool School. More recently the Kitasato Archives of Experimental Medicine has entered the field, affording opportunity for workers in the Orient to publish near at home. Just recently a long-felt want has been filled by the appearance of the American Journal of Hygiene and the American Journal of Tropical Medicine.

Continuing the task of placing in the hands of investigators a dependable and indispensable index of Medical and Veterinary Zoology, Stiles and Hassall (1912) have published their Index-Catalogue on Cestoda and Cestodaria. Its value over the Trematode Catalogue of the series consists in the more thoro analysis of specific and sub-specific citations with the page reference for each and in the fewer number of errors which inevitably creep into a work of such scope. The long-awaited companion volume on Roundworms has recently been issued (1920) and meets the expectations of the most critical reviewer. Along this line one cannot commend too highly the synopses of important papers relating to medical parasitology appearing in the Tropical Disease Bulletin. It is to be regretted, however, that the reviewers of this Bulletin have not seen fit to include certain other reviews which, altho technically non-medical, are fundamentally related to medical problems.

New species and new systematology in helminths are brought together in a most workable digest in the chapters on Platyhelminthes and Nemathelminthes in Ward and Whipple's Fresh-Water Biology (1918). Progress in American helminthology is shown in the fact that many of these species are described for the first time and in the introduction of a considerable portion on cercariae to the subchapter on trematodes. The data are made especially valuable by their relation to one another in the form of a key, and are made the more workable by ample illustrations.

The most comprehensive treatise on the subject of human parasitology which has appeared within the decade is Fantham, Stephens, and Theo-

bald's "Animal Parasites of Man" (1916), a book which has no equal in point of completeness and in up-to-the-minute information on human entozoa. The writing of a brief review of progress in this field gives an insight into the monumental character of this book. While strides have been made in the science ever since the publication of "Animal Parasites" it remains the reliable compendium and guide to the researcher or practitioner encountering entozoic ailments. In their Manual of Tropical Medicine (1919) Castellani and Chalmers have not only contributed greatly to the knowledge of tropical protozoa, helminths and arthropods from data largely drawn from their own wealth of experience in the Tropics, but they have likewise secured the permanent cooperation of the practitioner in problems of parasitology by presentng the clinical and pathological pictures of these parasitic infections. The manual stands as a lasting memorial to the junior author, who gave his life for the work.

Perusal of the literature of parasitology of the period which is covered in this review reveals a vast wealth of investigation, the major part of which falls within the group of the protozoa. Workers on protozoa have been many and a considerable share of their contributions significant. Certain problems like amebiasis have been studied in new fields. In other cases the life history has been elucidated. In many cases, however, mere symptomatology and diagnosis have been set down, where the lack of new data hardly warrants more than a statement of the case.

Foremost among workers in protozoology are those of the English Schools, comprising Stephens, Fantham, Nuttall, Yorke, Macfie, Wenyon and Porter. With these investigators life histories have played an important rôle. With them, too, detailed descriptions of morphological features have not been neglected. One is most convinced of the thoroness of the work of the Liverpool School in reviewing the elaborate and most detailed methods which have been followed in the experimental treatment of malaria.

Work on the Continent of Europe of a high character has been done by Laveran, Leger, França, Negri and Galli-Valerio. In the Americas Craig, Kofoid, Darling, Hadley, Chagas and Magalhaes have made noteworthy contributions, while Cleland's solution of dengue in Australia and Miyajima's studies on the tsutsugamuchi deserve the highest praise.

In the words of Wenyon (1915) our knowledge of trypanosomiasis and malaria has reached something like full fruition. Hardly so much can be said of the majority of protozoon infections, partly because the circumstances have not been favorable, partly because the investigations have been side tracked.

In 1911 Novy touched upon the progress that had been made in our knowledge of protozoan infections and their treatment. The life history of *Trypanosoma brucei* had just been demonstrated (1909) and remained

one of the outstanding discoveries of the decade. Little was known of the spirochaetes and their pathogenicity aside from the studies on treponema. The life history of the malarial plasmodium had been well authenticated, but other hematozoon forms were little known. Since then many groups have been carefully studied. Nuttall (1913) has found the life cycle of Babesia in dogs, horses and cattle to pass thru certain ticks as intermediate hosts and has discovered curative salts for these infections. Stephens (1914) describes a new tertian malarial parasite, *Plasmodium tenue*, from the Central Provinces, India. Yakimoff (1917) contributes to the knowledge of Piroplasma, Theileria, Nuttallia and Anaplasma infections of domestic and semi-domesticated animals of Russian Turkestan. Fantham (1910) and Hadley (1911) have given a clear morphological analysis of *Eimeria avium*.

Again, the studies of Ross and Thomson (1916) on Egyptian sand amebae show the necessity of preventing contamination of dry sand with fecal matter.

Wenyon and O'Conner (1917) have helped to solve the practical treatment of the protozoan infections of man in Egypt. They have been able to standardize treatment of amoebiasis. Three new human Parasites, *Waskia intestinalis* and *Tricercomonas intestinalis* and *Entamoeba nana* have been found in these studies.

Craig (1917) has established a basis for classification of amebae parasitic in man which allows one to profit from his numerous investigations in this field. He recognizes as valid species, *Craigia hominis* and *C. migrans*, *Endamoeba coli*, *E. histolytica* and *E. gingivalis*, and *Vahlkampfia lobospinosa*. A more conservative standard is presented by Dobell in his monograph on the amoebae (1919), a treatise which for its thoroness commands the attention and admiration both of the theoretical and the practical parasitologist.

Von Prowazek (1913) has published an important paper on *Balantidium coli*. He has carefully reviewed the geographical distribution of the species, described its histology in minute detail and methods of propagation, and has worked out its pathogenicity.

Work of the character of Fantham and Porter's (1914) contribution to the life-history of *Nosema bombi* has been of increasing importance in elucidating the general knowledge of protozoan life cycles and thus contributing indirectly to a knowledge of related human forms where experimental infections are obviously less possible. In reviewing the work on protozoa one is struck by the mass of such work of an excellent character of which lack of space unfortunately does not even permit mention.

Watson's monograph (1916) on Gregarines constitutes a well organized synopsis of new and described species of the group, many species of which had previously been investigated only piecemeal

Dobell (1918) has contributed a valuable memoir in his study of human coccidia. Following up the work of Wenyon (1915) he has described three definitely known species infecting man (*Isospora hominis* Riv. 1878, *Eimeria wenyoni* n. sp. and *E. oxyspora* n. sp.,), in addition to throwing doubt on the identity of a third Emeria species as that of the rabbit (*E. stiedae*).

Moroff (1915), after a searching investigation, places the sarcosporidia close to the gregarines and coccidian forms in the subclass Telosporidia, along with the Haemosporidia.

Wolback's work on the Rocky Mountain spotted fever (1918) has shown that the causal agent of the disease is a minute parasite, present in the blood of infected mammals and in ticks which are capable of transmitting the disease.

Kudo's monograph on the Myxosporidia (1920) is memorable not only as a collation of the work of earlier investigators, but as a survey of the large number of myxosporidian forms studied by Kudo himself.

The work of Poche (1913) on the System of Protozoa is a comprehensive treatment of nomenclature of the group. It is notable for the large number of new orders, suborders and families proposed, many of which are readjustments of rank justified by the increase in number of the group. With the wealth of knowledge of morphology and life histories of the Protozoa careful systematic readjustments of this type are increasingly necessary.

Work on the helminths has been continued by many of the investigators who have already established a name for themselves among parasitologists. In Europe Odhner has contributed further studies to his work on phylogeny and systematology, among the most interesting of which are those on Schistosome and Holostome groups. Goldschmidt has extended his investigations on cytology most successfully. Kossack has monographed the monostomes, while Monticelli and Lühe have contributed much to the knowledge of trematodes. Fuhrmann, Leon and von Ratz have studied the cestodes while Railliet and Henry and Seurat have made notable contributions to the nematodes. The most brilliant work of the younger helminthologists in Europe is undoubtedly that by Leiper.

In America such studies have been continued by Ward, Ransom and Young on Cestodes, by Ward on Trematodes, and by Ward and Ransom on nematodes. In addition there has arisen in the United States a considerable group of younger investigators, of whom La Rue, Cort, Boeck and Van Cleave deserve prominent mention.

In Japan Katsurada, Fujinami and Goto have produced work of high merit. Yoshida, Okanama, Kobayashi and Miyairi have added much to life-history problems.

The contributions on Australian helminths count among their number the investigations of Nicoll, Cleland, S. J. Johnston, T. H. Johnston,

Breinl and Sweet. This summary of important contributors to the science would not be complete without mention of Ssinitzin, Skrjabin and Yakimoff for Russia and Southwell for India.

Ward (1917) has emphasized the necessity of rearranging forms "so as to express better their correct relationships in the light of more perfect knowledge of their structure." But he adds the essential corollary that it has been his fixed principle never to make any change until he was personally familiar with the form discussed or had acquired such acquaintance with its structure as to know that some change was inevitable and that the proposed modification was defensible on morphological grounds. On this basis he has made fundamental but conservative changes in trematode and acanthocephalan groups and has established order in the nematode group where previously taxonomy was confined most usually to mere descriptions of new species.

The period has experienced an advance in helminthology from an almost purely zoological science to one ministering to the needs of comparative bionomics and medicine.

The outstanding morphological and systematic contribution to our knowledge of the Cestoda during recent years is La Rue's Monograph on the Family Proteocephalidae (1914). Provided with a wealth of American material, supplemented by more than on ordinary amount of types of the group described by European and other workers, La Rue has been enabled to mold the material into a comprehensive and practically exhaustive treatise. His descriptions and drawings are detailed, yet clear, his types are well defined and the amount of material collected, the amount used in study and the location of each specimen in the collection are minutely set down. Added to this are valuable synoptic tables and a workable natural key to the group. The contribution as a whole is such as to place the author immediately in the rank of the foremost helminthologists.

Recently Cooper (1919) has monographed another group of cestoda from fishes which contributes to our knowledge in that group.

Among other contributions on cestode anatomy and phylogeny the work of Douthitt (1915) on Anoplocephalidae is worthy of mention. Because of the care which this investigator used in working over his material and the gradual way in which he built up a natural classification of the group the monograph will serve as a lasting memoir to his efforts.

Ransom (1913) has made possible the statement that *Cysticercus ovis* is the intermediate stage of a dog tapeworm, *Taenia ovis* (Cobbold) Ransom and in working out the life-history of this cestode experimentally has solved a problem of long standing. This species in the bladder-worm stage has thus been proved to be distinct from *Cysticercus cellulosae* and the adult from *Taenia tenella*, *T. solium*, *T. hydatigena*, and *T. marginata*. Treatment of dogs for the tapeworm is found not only to eradicate this per-

plexing economic problem of sheep measles but rids them of other worms of equally serious pathogenicity.

Beddard (1911–1914) has contributed studies from time to time, making known to science a large number of cestodes parasitic in animals in the Zoological Society Gardens (London). Likewise Skrjabin (1914) has contributed to our knowledge of the Cestoda of birds of Russian Turkestan. Fuhrmann (1918) in a detailed survey of the avian cestodes from New Caledonia and Loyalty Isle adds materially to the knowledge of the families Tetrabothriidae, Anoplocephalidae, Davaineidae, Dilepididae, Hymenolepidae, Acoleidae and Amabiliidae.

Thus the comparative work on cestodes has been greatly advanced.

The striking advances in our knowledge of the trematodes have come as life-history problems. Members of the medical profession have been especially sympathetic to this work because it was concerned with flukes most of which affected man. It is particularly noteworthy that all of these without exception have borne out the principle established for *Fasciola hepatica*, that the miracidium penetrates a mollusk, and from the mollusk the cercaria emerges which reaches its definitive host (immediately or intermediately according to the group to which the species belongs) and there becomes mature. Faust (1918) following Ssinitzin's work (1911) has found the sporocyst and the redia stages to be true parthenitae.

A problem which Looss had repeatedly attempted to solve in Egypt and on which Katsurada and Fujinami have contributed much in Japan was the schistosome life history. Credit for the first solution of the life cycle is due to Miyairi and Suzuki (1914) in Japan and later to Leiper and Atkinson for Japanese species and Leiper (1915) for the two Egyptian species. A clear understanding that the miracidium enters a gasteropod and that by change of cycle the cercaria emerges from the snail and directly infects man thru the skin or the mouth has made possible methods for preventing the disease. It has also made possible a clear restatement of the thesis that "The larval metamorphosis of all digenetic trematodes occurs without known exception in the bodies of molluscs belonging to the classes Gasteropods and Lamellibranchia." Leiper (1918) has shown that when once infected the patient is practically incurable. He has found from his Egyptian Researches that

"(1) Transient collections of water are quite safe after recent contamination.

"(2) All permanent collections of water, such as the Nile, canals, marshes and birkets, are potentially dangerous, depending upon the presence of the essential intermediary host.

"(3) The removal of infected persons from a given area would have no effect, at least for some months, in reducing the liability to infection, as the intermediate hosts discharge infective agents for a prolonged period.

"(4) Infected troops can not reinfect themselves or spread the disease directly to others. They could only carry the disease to other parts of the world where a local mollusc could efficiently act as a carrier.

"(5) Infection actually takes place both by the mouth and through the skin.

"(6) Infection in towns is acquired from unfiltered water which is still supplied, ever in Cairo, in addition to filtered water, and is delivered by a separate system of pipes.

"(7) Eradication can be effected without the cooperation of infected individuals by destroying the molluscan intermediaries."

Nakagawa (1916) has unravelled the life cycle of *Paragonimus Westermani*, showing that the cercaria is developed in Melania species and the encysted larva in Potamon. These infected crabs when fed to puppies gave rise to typical pulmonary paragonimiasis. Moreover the route of infection has been found to be from the intestinal wall in the vicinity of the jejunum, thru the abdominal cavity, thru the diaphragm and pleural lining, where it bores thru the lung tissue and encysts. Yoshida, working on the same problem entirely independently in Japan, was able to substantiate Nakagawa's results. Kobayashi's work on this fluke in Korea (1918) has hardly as convincing data as those of his colleagues. On the other hand the latter investigator (1915) has clearly shown experimentally that the encysted larva found in several species of Japanese fresh-water fish develops into the human fluke, *Clonorchis sinensis*. Thus far, however, he has not worked out the cercarial phase of the life-history of this worm. Nakagawa (1921) has just published his experimental work on *Fasciolopsis buski*, which he finds to infect the hog as the encysted post-cercarial distomule.

Recently interest in larval trematodes has been revived and the field for study of this group in America has been studied by Cort and Faust, who have shown that specific marks of discrimination in cercariae are important even tho they are minute. These investigators have added data on the larvae which should facilitate life history studies on flukes. Among these studies are those on flame-cell constancy and homology, including the use of this system as a basis for systematic relations. Of importance both to pure science and to medical parasitology, Cort's monograph (1919) on the cercaria of the Japanese blood fluke sets a record for careful study and detail in this group. Furthermore, Cort's study on the stages of development of the schistosome in the definitive host (1921) makes a valuable addition to the ontogeny of the fluke.

One can not overlook the researches of Ssinitzin (1911) in this field. This investigator has not only presented data on many interesting and unique larval flukes, but has presented theories of their phylogenetic relations which are at least extremely suggestive and stimulating.

A morphological paper which has done much to show the necessity of exactness in differentiation of closely related species is that of Ward and Hirsch (1915) on the species of Paragonimus. These authors have found the type, size and group relationships of the spines to be distinctly diagnostic, and this fact, coupled with the importance of one of these species to medical science in the Orient makes the work especially significant.

Comparatively few investigators have made important studies during the past decade on the morphology and systematology of parasitic nematodes. Railliet and Henry in France and Ward and Magath in America have published researches which constitute marked exceptions to this lack of such investigation in this group. The first significant analysis of the parasitic Nematodes in America is embodied in Ward's chapter on these worms in Ward and Whipple's Fresh-Water Biology (1918).

A most important contribution to the morphology of the nematode is embodied in Magath's monograph of *Camallanus americanus* (1919). This thesis constitutes the most significant work on a single nematode species since the researches of Looss on *Ancylostoma duodenale*. The writer describes in detail the organs and systems of the worm and arrives at the conclusion that formulae for measurement are not dependable but that where doubt arises in systematalogy there remains only the accurate morphological description of every organ and part of the form in question.

The most widespread campaign ever undertaken by governmental or private interest for the eradication of a particular disease is that which was undertaken by the Rockefeller Foundation for the banishment of hookworm from the earth. In 1909 the Rockefeller Sanitary Commission was created to combat the hookworm in the United States. The findings of this Commission of the prevalence of the worm, the "arrest of physical, mental and moral growth, great loss of life, and noticeable decrease in economic efficiency," together with the success which attended treatment of hookworm infection, led to the establishment in 1913 of the International Health Commission (afterwards known as the International Health Board) with the purpose in view of "extending to other countries the work of eradicating hookworm disease as opportunity should offer" and, so far as practicable, to follow up the treatment and cure of this disease with the establishment of agencies for the promotion of public sanitation and the spread of the knowledge of scientific medicine.

Forthwith this commission proceeded to determine 1) the geographic distribution and the approximate degree of infection, 2) to examine microscopically the cases and cure those infected, and 3) to establish sanitary conditions which would prevent soil-pollution.

At the close of 1918 the Board had solely or cooperatively attacked the problem in the Southern United States, Central Mexico, Cuba, Porto Rico, Jamaica, a considerable share of South America, Egypt, Ceylon,

Siam, The Malay, South China, New Guinea, Papua, Java, Guam, and Queensland, Australia, and new work was under way in the Madras Presidency, India.

While the intensive method of microscopic examination and treatment of patients within a limited area was utilized, the more fundamental purpose of the campaign has been to develop an education propaganda for better sanitary conditions so that the sources of infection will be eliminated.

One of the fundamental life-history problems which has engaged the attention of investigators in several geographically different centers is that of Ascaris. Captain Stewart of the Indian Medical Service (1917, 1918) has shown that *Ascaris lumbricoides*, and *A. mystax* can be developed to a certain larval stage in the mouse and rat.

Ransom and Foster (1917, 1919, 1920) have been able to produce individuals more nearly mature in the sheep and goat. The latter writers have shown, however, that these stages of development in animals other than the hog and man do not necessarily imply that the mouse, or rat, sheep or goat serve as intermediate hosts for these parasites. Yoshida (1919), working on guinea-pigs, was able to trace the life history as follows: "The ascarid larvae escape from the egg shell in the intestine of the host and proceed to the abdominal cavity by boring through the wall of intestine. Thence they pierce the diaphragm to enter the pleural cavity, finally penetrating into the lungs from their surface. . . . Furthermore, the lungs are the only necessary and important organ to be passed by the larvae in the course of their development. . . . (They) continue their development and migrate to the mouth cavity through the trachea, again passing down the alimentary canal to the intestine of the host.

Work on the Acanthocephala has been relatively meager. Lühe's digest of the group (1911) has given a basis for Continental investigations while Van Cleave's numerous studies on American species constitute marked progress in methods and thoroness of investigation.

Almost the entire amount of our knowledge of insects in the rôle of carrier and intermediate hosts of parasitic disease has come within the last few years. It is within this period that the life histories of the trypanosome, the piroplasmas and the spirochaetes have been shown to develop in specific flies, fleas, bugs or lice as the case may be. Moreover, certain tapeworms, especially those of poultry, have been just recently shown to develop as larvae within insect hosts. Finally there is further proof of the importance in the spread of parasitic disease when the insect acts merely as a vector. For these reasons important campaigns against these several insects have been carried on by private forces and by government agencies, foremost of which is the all but complete eradication from the Western Hemisphere of yellow fever by controlling the mosquito transmitting the

disease, with plans under way for a campaign on this insect in the remaining locus of infection.

Thus a considerable share of the problems which confronted parasitology at the beginning of the decade have been carried to completion while others are being gradually sifted out. In their place, however, have come still others which require the greater skill and the wider point of view for their full solution. All of these signs of progress in parasitology indicate that this science is rapidly coming to assume the place which it deserves as the companion of bacteriology and gross pathology.

IMPORTANT LITERATURE ON PARASITOLOGY

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